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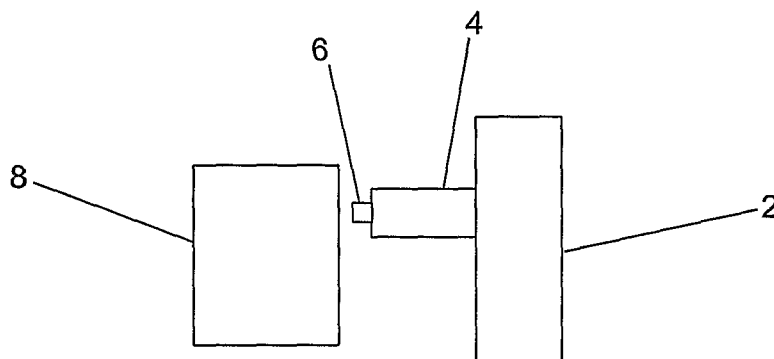
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(54) Title: APPLICATIONS OF ULTRASONIC PROBES



(57) Abstract: The present invention relates to applications of ultrasonic probes, such as ultrasonic thickness gauges, ultrasonic flaw detection apparatus and ultrasonic imaging devices. In some forms of the invention, the ultrasonic probe is a wireless ultrasonic probe; amongst other advantages, this enables the probe to be used in situations that were not previously possible. In some forms of the invention, the ultrasonic probe is one of many tools available to a CNC Machining Centre.



WO 2008/012535 A2

Applications of Ultrasonic Probes

The present invention relates to applications of ultrasonic probes, such as ultrasonic thickness gauges, ultrasonic flaw
5 detection apparatus and ultrasonic imaging devices.

It is well known that ultrasonic probes can be used as thickness gauges, as a means of detecting internal flaws and as a means for creating images of the internal structures of
10 optically opaque materials. Most ultrasonic techniques work by emitting a high frequency acoustic pulse into a component and monitoring the echoes received back from within the component.

15 For thickness gauging, the time taken for the signal to pass through that component, reflect off the opposite side of the component and return to the transducer that emitted the pulse is measured. If the speed of sound through the component is known (or can be measured), then the thickness
20 of the component can be determined to a high degree of accuracy. Given that ultrasonic probes can be used to measure thickness of material to a high degree of accuracy, such probes can be used to ensure the consistent manufacture of parts.

25 For flaw detection, the echoes created by acoustic impedance mismatches are detected and used to identify the whereabouts and nature of these impedance changes as defects or other features in the component. Echo detection is also used in
30 ultrasonic imaging.

- 2 -

The consistent manufacture of quality parts requires the accurate measurement of the dimensions of a workpiece, and the defect population within it. Computer Numeric Control (CNC) Machining Centres and Co-ordinate Measuring Machines (CMMs) are two exemplary types of apparatus that enable precision measurements of the positions of surfaces of a component in a co-ordinate system for use in a manufacturing process. A key aspect of CNC machines and CMMs is the ability of those devices to measure component positions and, in the case of CNC machines, to position tools to accuracies typically in the region of thousandths of a millimetre.

A CNC Machining Centre is used for shaping a workpiece (often, but not always, metal) under the control of a computer. Computer Numeric Control is the term given to the operation of a machine, for example a lathe, under the control of a computer.

With a CNC Machining Centre, a computer controls every aspect of the shaping process, including the selection of each tool to be used from a carousel that might hold over 100 different tools. The objective is to enable an operator to load a set of instructions from an external computer relating to engineering drawings and to enable the CNC machine to take over and carry out the processes required with no further operator intervention.

A key element of CNC machines is the ability to position a tool and the workpiece in relative positions within the automated process to very high degrees of accuracy. This is essential if the instructions for shaping the workpiece are to be accurately implemented, without the intervention of a

- 3 -

skilled operator. In order to achieve this, a CNC Machining Centre is provided with a number of position sensors and motors, in addition to cutting tools.

- 5 Co-ordinate measuring machines (CMMs) are used to make quick and accurate dimensional measurements. CMMs function by contacting a workpiece with a probe. The purpose of a CMM is to make accurate measurements: CMMs do not have a cutting function.

10

CMMs and CNC Machining Centres are established, mature technologies for measuring the outside surfaces of components.

- 15 A problem with existing measurement systems is the lack of integration between the measurement of external dimensions, and the measurement of internal dimensions.

- A problem with existing ultrasonic probes is that they are
20 not well adapted for use in hostile environments. Further, many existing ultrasonic probes are not well adapted for automated use.

- The present invention seeks to address at least some of the
25 problems outlined above.

- The present invention provides an ultrasonic probe comprising a wireless transmitter for transmitting data obtained by said probe. The ultrasonic probe may be
30 suitable for use as one or more of a thickness gauge, a flaw detection apparatus and an imaging device.

- 4 -

The present invention also provides a method of measuring dimensions of a component mounted in an apparatus, the method comprising the steps of using a wireless ultrasonic probe to determine the thickness of said component and transmitting data obtained by said probe to a central controller.

The present invention further provides a method of detecting a defect population of a component mounted in an apparatus, the method comprising the steps of using a wireless ultrasonic probe to determine the defect population of said component and transmitting data obtained by said probe to a central controller.

The present invention yet further provides a method of imaging a component mounted in an apparatus, the method comprising the steps of using a wireless ultrasonic probe to image the said component and transmitting data obtained by said probe to a central controller.

Conventional ultrasonic probes use cables to transfer the data obtained, which cables restrict the potential applications of such devices.

In one form of the invention, the transmitter is a radio-frequency transmitter; for example, a transmission system making use of the well-known BluetoothTM protocol could be used. However, there are many alternative forms of transmitter that could be used, such as an optical transmitter, or other radio frequency wireless techniques.

- 5 -

The said wireless transmitter may be sealed within said probe. This is advantageous in hostile environments, since the transmitter would be protected from that environment.

- 5 In one form of the invention, the ultrasonic probe comprises an internal power source. This power source may be sealed within the probe. This is advantageous in hostile environments, since the power source would be protected from that environment. In one embodiment of the invention, the
10 ultrasonic probe comprises a wireless transmitter and a power source that are both sealed within the probe.

- The present invention also provides: an apparatus for measuring dimensions of a component mounted in the
15 apparatus, the apparatus comprising an ultrasonic probe for measuring the thickness of said component; an apparatus for detecting the defect population of a component mounted in the apparatus, the apparatus comprising an ultrasonic probe for detecting the said defect population; and/or an
20 apparatus for imaging a component mounted in the apparatus, the imaging device comprising an ultrasonic probe for imaging the said component.

- By way of example, the apparatus may be a Computer Numeric
25 Control (CNC) Machining Centre or a Co-ordinate Measuring Machine (CMM). The provision of an ultrasonic probe having a wireless transmitter adds flexibility to such apparatus and is particularly advantageous when used as part of a CNC Machining Centre, since CNC Machining Centres often present
30 hostile environments to which the ultrasonic probe of the present invention is well suited.

- 6 -

The apparatus may further comprise means for measuring the position of an external surface of said component. Given data concerning the external surface of said component and the thickness data obtained from said probe, the position of the internal surface of said component can be determined with a high degree of accuracy. The ultrasonic probe may itself be used to measure the position of an external surface of said component. Alternatively, a different tool may be used to measure the position of the said external surface.

The apparatus may be used to modify the cutting parameters to be used by the CNC machine based on the measurement of the external surface and thickness.

In one form of the invention, the said ultrasonic probe is one of a plurality of devices available for use by said apparatus. These devices may be provided in a carousel of devices. In one form of the invention, in excess of 100 such devices may be provided.

The said plurality of devices may include at least one cutting tool.

The apparatus may include a means for selecting one of said plurality of devices for use. In one form of the invention, the said means is a robotic selecting means.

The said ultrasonic probe may comprise a transmitter for transmitting data obtained by said probe. The said transmitter may be a wireless transmitter. In one form of the invention, the transmitter is a radio-frequency

- 7 -

transmitter; for example, a transmission system making use of the well-known Bluetooth™ protocol could be used, or other radio frequency wireless techniques. However, there are many alternative forms of transmitter that could be
5 used, such as an optical transmitter.

The said wireless transmitter may be sealed within said probe. This is advantageous in hostile environments, since the transmitter would be protected from that environment.

10

In one form of the invention, the ultrasonic probe comprises an internal power source. This power source may be sealed within the probe. This is advantageous in hostile environments, since the power source would be protected from
15 that environment. In one embodiment of the invention, the ultrasonic probe comprises a wireless transmitter and a power source that are both sealed within the probe.

The said apparatus may, for example, be a Computer Numeric
20 Control (CNC) Machining Centre or a Co-ordinate Measuring Machine (CMM).

The present invention further provides methods of: measuring dimensions of a component mounted in an apparatus, the
25 method comprising the steps of selecting an ultrasonic probe from a plurality of available devices and determining the thickness of said component using said ultrasonic probe; detecting a defect population of a component mounted in an apparatus, the method comprising the steps of selecting an
30 ultrasonic probe from a plurality of available devices and determining the defect population of said component using said ultrasonic probe; and/or imaging a component mounted in

- 8 -

an apparatus, the method comprising the steps of selecting an ultrasonic probe from a plurality of available devices and imaging said component using said ultrasonic probe.

- 5 The step of determining the thickness of said component may include positioning said ultrasonic probe in contact with an external surface of said component.

The method may further comprise the step using said
10 ultrasonic probe to determine the position of the external surface of said component, for example by determining the position of said ultrasonic probe.

The apparatus may be used to modify the cutting parameters
15 to be used by the CNC machine based on the measurement of the external surface and thickness.

The method may further comprise the steps of: selecting a second probe from the plurality of available devices and
20 using said second probe to determine the position of the external surface of said component. The step of determining the position of the external surface of said component may include positioning the second probe in contact with the external surface of said component and determining the
25 position of said second probe.

The said selecting steps may be carried out by a robotic selecting means.

30 The said ultrasonic probe may be a wireless ultrasonic probe.

- 9 -

An apparatus and method in accordance with the present invention will now be described, by way of example only, with reference to the accompanying schematic drawings of which:

5

Fig. 1 is a schematic view of an apparatus in accordance with an embodiment of the invention; and

Fig. 2 is a block diagram demonstrating the functionality of an ultrasonic probe in accordance with an embodiment of the present invention.

10

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Figure 1 shows a CNC machine 2 that is being used to shape a workpiece 8. The CNC machine 2 includes a cutting spindle 4. An ultrasonic probe 6 is shown mounted in the spindle of the CNC machine 2.

20

The spindle 4 is an industry standard cutting tool holder. The ultrasonic probe 6 is mounted in the spindle 4 and used in the same way as any other tool that might be available for use by the CNC machine. As noted above, such tools might be housed in a carousel and in excess of 100 tools may be available for use.

25

30

In use, the CNC machine 2 is controlled by a computer programme in a manner well known in the art. In order to make use of the ultrasonic probe 6, a tool robot, under the control of the CNC control programme, places the ultrasonic probe into the spindle 4 as shown in Figure 1. The CNC control programme then positions the ultrasonic probe at the required position over the workpiece 8 in order for the probe to carry out its required function (such as measuring the thickness of the component, detecting flaws in the

- 10 -

component or imaging the component). The ultrasonic system also measures the location of the front face of the component, if required. This process can be repeated as many times as necessary and is always under the control of the CNC control computer. The data obtained by the ultrasonic probe may be stored for future use.

Alternatively, or in addition, that data may be used by the CNC control programme to adjust a cutting operation. In this manner, the measurements made by the ultrasonic probe can be used as part of a closed-loop feedback system used to control the cutting of the workpiece 8.

Figure 2 is a block diagram of an ultrasonic probe 10 in accordance with an embodiment of the present invention. The ultrasonic probe 10 comprises an ultrasonic transducer 12, a controller 14, a transceiver 16 and a power source 18.

In use, the ultrasonic transducer 12 is arranged to transmit ultrasonic pulses under the control of the controller 14 and to receive ultrasonic pulses and pass data relating to those pulses to the controller 14. The controller receives control information, for example from the CNC machine 2, via the transceiver 16. Data is transmitted by the transceiver 16, for example to the CNC machine 2, under the control of the controller 14. The ultrasonic transducer 12, controller 14 and transceiver 16 receive power from a power source 18.

Each of the elements of the ultrasonic probe 10 may be sealed within a probe assembly such that the probe can be used in hostile environments.

- 11 -

Although the present invention has generally been described with reference to CNC Machining Centres and CMMs, the invention is not so limited. For example, the wireless probe has many applications, in particular in hostile environments including, but not limited to, nuclear reactors, high pressure locations and any location that is difficult to access. There are many applications where the communication between the ultrasonic probe and its associated electronic receiver cannot be made via wires.

10 For example embodiments of the present invention are planned for mounting in various forms of rotating machinery such as lathes and railway wheels in which the use of ultrasonics would be advantageous but are presently precluded because of the necessity to use wire connectivity.

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- 12 -

CLAIMS:

1. An ultrasonic probe suitable for use as a thickness gauge, a flaw detection apparatus and/or an imaging device,
5 said ultrasonic probe comprising a wireless transmitter for transmitting data obtained by said probe.
2. An ultrasonic probe as claimed in claim 1, wherein said transmitter is a radio-frequency transmitter.
- 10 3. An ultrasonic probe as claimed in claim 1 or claim 2, wherein said wireless transmitter is sealed within said probe.
- 15 4. An ultrasonic probe as claimed in any one of claims 1 to 3, wherein said ultrasonic probe comprises an internal power source.
- 20 5. An ultrasonic probe as claimed in claim 4, wherein said internal power source is sealed within said probe.
- 25 6. An apparatus for measuring dimensions of a component mounted in the apparatus, the apparatus comprising an ultrasonic probe for measuring the thickness of said component.
- 30 7. An apparatus for detecting a defect population of a component mounted in the apparatus, the apparatus comprising an ultrasonic probe for detecting the said defect population.

- 13 -

8. An apparatus for imaging a component mounted in the apparatus, the apparatus comprising an ultrasonic probe for imaging the said component.

5 9. An apparatus as claimed in any one of claims 6 to 8, further comprising means for measuring the position of an external surface of said component.

10 10. An apparatus as claimed in any one of claims 6 to 9, wherein said ultrasonic probe is one of a plurality of devices available for use by said apparatus.

11. An apparatus as claimed in claim 10, wherein said plurality of devices includes at least one cutting tool.

15 12. An apparatus as claimed in claim 10 or claim 11, further comprising means for selecting one of said plurality of devices for use.

20 13. An apparatus as claimed in claim 12, wherein said selecting means is a robotic selecting means.

14. An apparatus as claimed in any one of claims 6 to 13, wherein said ultrasonic probe comprises a transmitter for
25 transmitting data obtained by said probe.

15. An apparatus as claimed in claim 14, wherein said transmitter is a wireless transmitter.

30 16. An apparatus as claimed in claim 15, wherein said wireless transmitter is sealed within said probe.

- 14 -

17. An apparatus as claimed in claim 15 or claim 16,
wherein said transmitter is a radio-frequency transmitter.

18. An apparatus as claimed in any one of claims 6 to 17,
5 wherein said ultrasonic probe comprises an internal power
source.

19. An apparatus as claimed in any one of claims 6 to 18,
wherein said ultrasonic probe is a sealed unit.

10

20. An apparatus as claimed in any one of claims 6 to 19,
wherein said apparatus is a Computer Numeric Control
Machining Centre.

15 21. An apparatus as claimed in any one of claims 6 to 19,
wherein said apparatus is a Co-ordinate Measuring Machine.

22. A method of measuring dimensions of a component mounted
in an apparatus, the method comprising the steps of using a
20 wireless ultrasonic probe to determine the thickness of said
component and transmitting data obtained by said probe to a
central controller.

23. A method of detecting a defect population of a
25 component mounted in an apparatus, the method comprising the
steps of using a wireless ultrasonic probe to determine the
defect population of the said component and transmitting
data obtained by said probe to a central controller.

30 24. A method of imaging a component mounted in an
apparatus, the method comprising the steps of using a
wireless ultrasonic probe to image said component and

- 15 -

transmitting data obtained by said probe to a central controller.

25. A method of measuring dimensions of a component mounted
5 in an apparatus, the method comprising the steps of selecting an ultrasonic probe from a plurality of available devices and determining the thickness of said component using said ultrasonic probe.

10 26. A method of detecting a defect population of a component mounted in an apparatus, the method comprising the steps of selecting an ultrasonic probe from a plurality of available devices and detecting defects in the said component using said ultrasonic probe.

15 27. A method of imaging a component mounted in an apparatus, the method comprising the steps of selecting an ultrasonic probe from a plurality of available devices and imaging said component using said ultrasonic probe.

20 28. A method as claimed in any one of claims 25 to 27, further comprising the steps of selecting a second probe from the plurality of available devices and using said second probe to determine the position of an external
25 surface of said component.

29. A method as claimed in any one of claims 25 to 28, wherein said selecting steps are carried out by a robotic selecting means.

30 30. A method as claimed in any one of claims 22 to 29, further comprising the step of using said ultrasonic probe

- 16 -

to determine the position of an external surface of said component.

31. A method as claimed in any one of claims 22 to 30,
5 wherein said ultrasonic probe is a wireless ultrasonic probe.

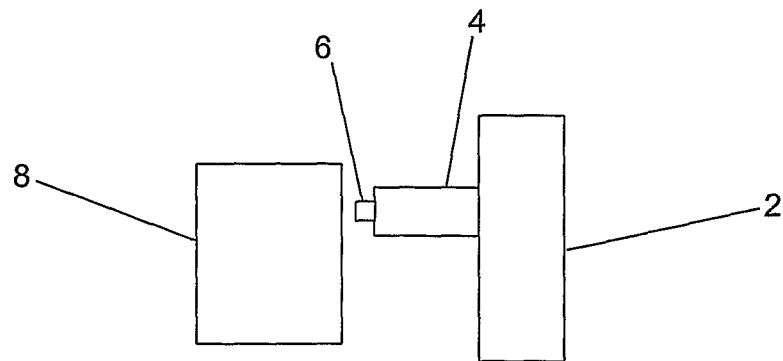


Fig. 1

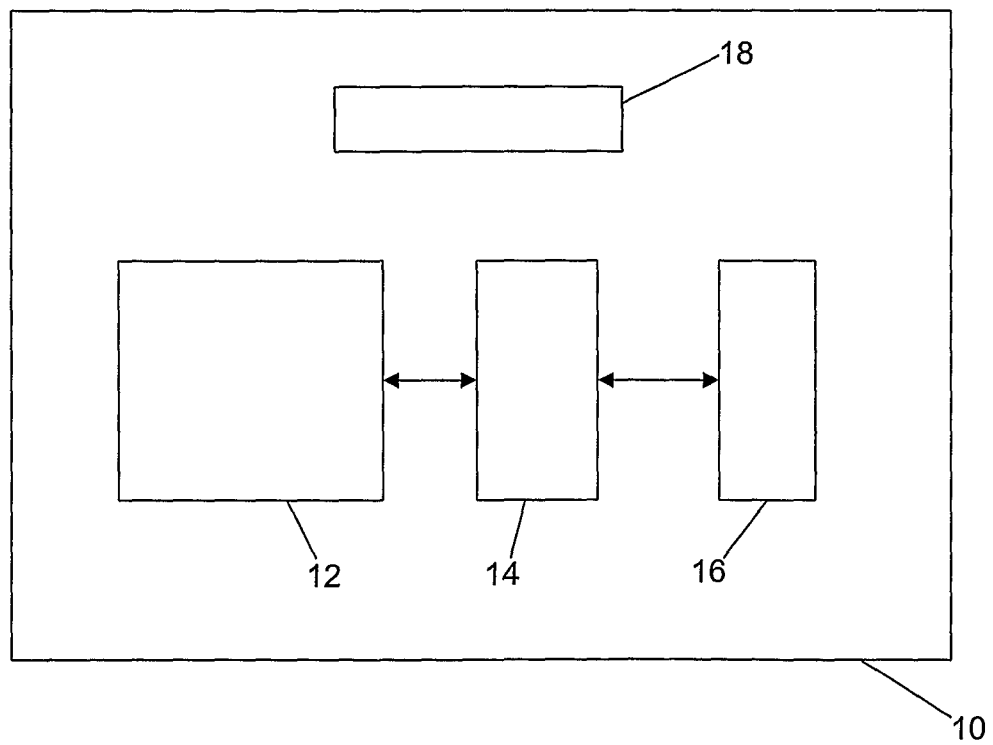


Fig. 2